RECOMMENDATIONS FOR RESEARCH IN NUCLEAR PHYSICS

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I. Introduction.

The recommendations for research in physics which are presented below have been limited entirely to nuclear physics. A large amount of the research and development which applies specifically to fast or slow neutron reactors and other uses of nuclear power do not fall within these boundaries.

The suggestions presented here are made in a very general form. For example, scattering measurements of various types are recommended to be carried out for materials which are deemed of possible use as reflectors, moderators, or active material. The present considered list of these elements can easily be given, but it is likely at this stage that the whole question of likely materials should be reopened. There has been no attempt to indicate how the proposed measurements should be instrumented, but in many cases present methods or extensions of those methods can be applied. To a very considerable extent, the fundamental nuclear information which is needed for the various applications of nuclear power is the same, but the energy region for which it is particularly needed may differ somewhat. The proper emphasis on the energy region most important in a given problem should be made accordingly.

It is inevitable that these recommendations are incomplete. Each experiment which is carried out will probably suggest several others. The present recommendations are largely those experiments which have not been successfully concluded thus far or which have been suggested from results obtained in the course of the past work.

II. Fundamental Research.

The use of nuclear reactions as practical sources of energy depends upon a more complete understanding of nuclear structure. No amount of applied research will lead to long-range success without an adequate understanding of atomic nuclei. Unfortunately, present day knowledge of atomic nuclei is exceedingly fragmentary. This includes the problem of nuclear fission as well as the basic problem of nuclear forces.

Not only should the more or less routine work in nuclear physics such as studies of nuclear scattering, nuclear reactions, and radioactivity be encouraged, but also such work as the study of cosmic rays and molecular beams. One important entity in the understanding of nuclear forces will surely be the mesotron. Studies on the production and nature of these interesting particles using very high energy (above 100 Mev) accelerating machines should be supported. In general, whenever a field of investigation is turned up that has even a remote bearing on the subject of nuclear physics, the possibility must not be overlooked that this new field may contribute in a most important way to the development of nuclear power.

By its very nature, a program of research to obtain these ends cannot be written down explicitly. Inasmuch as research in nuclear physics has become increasingly expensive, it is likely that financial support of fundamental research by the Government will be necessary for its continued success. If this support is not forthcoming from other agencies in the Government, it should be supported in the development of atomic power.

III. Programmatic Research

A. General Nuclear Research

1. A more complete understanding of the fission process is essential. A detailed program for this study is necessarily incomplete because it borders on the problems of fundamental research. There are, however, several questions which clearly need investigation.

The general problem of the fission spectrum and the number of neutrons per fission as a function of the energy and kind of the incident particle is quite inadequately known. Some information now exists on the fission spectrum in the region above 1 Mev. This needs verification, and the spectrum should be obtained at lower energies. There has been some indication of very high energy neutrons above 10 Mev from the fission process, and this question should be studied.

Information should be obtained about the distribution both in energy and among the chemical isotopes of the fission fragments as a function of the energy of the incident neutron. More work is needed on the angular distribution of emitted neutrons with respect to the direction and energy of the fission fragments. A better measurement of the statistical fluctuation in the number of neutrons per fission should be made.

The periods and energies of the delayed particles such as neutrons, gamma rays and electrons should be investigated.

The measurements of the spontaneous fission need extension.

The number and energy of the prompt alphas and gammas from fission should be investigated as a function of the energy of the incident neutron. A search for other particles should be made. The excitation of fission by protons, deuterons, electrons and gamma rays in particular needs further study. It may be possible to excite fission by fission fragments, and this should be ascertained.

An effort should be made to obtain the angular momentum of pertinent nuclear levels and particularly the angular momentum of the ground states of fissionable materials.

2. Cross section investigation.

a. The measurements of fission cross section as a function of energy for all fission producing isotopes should be extended over a wider energy region. The fission cross sections of the short period Th 233 and U 239 should be measured. An exploration should be made of other isotopes, particularly of heavy elements, as possible fission producing materials.

b. Neutron absorption cross sections should be systematically investigated with particular attention to elements which show fission or seem promising as reflectors. The variation of absorption cross section with energy of the incident neutron should be measured, and particular attention should be paid to the problem of the competition of absorption with fission.

c. The cross section for elastic scattering of neutrons as a function of the energy of the incident neutron and direction of the scattered neutrons should be investigated with emphasis on those isotopes which show fission or may be of use as neutron reflectors.

d. The problem of the inelastic scattering of neutrons by nuclei is now very inadequately understood. The cross section for inelastic scattering as a function of the energy of the incident neutron should be investigated for all materials, particularly those which seem likely for use in neutron reactors.

This study should include a determination of the energies to which the scattering process degrades the neutrons. The energy and number of gamma rays which are released after inelastic scattering should also be determined.

e. Cross sections for other nuclear reactions of materials likely to be used in nuclear reactors should be measured; the n-2n reaction in particular, but also the n-α, n-p, etc. reactions.

f. The cross sections for nuclear excitation by gamma rays, particularly of materials used in nuclear reactors should be determined.

3. The possible formation of elements beyond those now produced in the periodic table should be investigated and a systematic study of their properties made. An examination should also be made of the artificial production of isotopes with high fission cross sections from elements now readily available.

4. A study should be made of all α, γ, and β rays from radioactive elements to enable disintegration schemes to be made.

5. Instrumentation. In order to carry out all the research indicated above, it will be necessary to invent and perfect many new detecting devices. A systematic exploration and development is necessary, but a good detector is usually the result of an inspiration.

There should be a systematic exploration of possible new isotopes produced from pile irradiation for use as detectors as well as for photo neutron sources. Separation of known isotopes in large quantities, such as B_{10}, will be useful in instrumenting experiments.

Accelerating equipment must necessarily play a very important role in both the fundamental research and the programmatic research. Electrostatic generators have been used extensively for the production of monochromatic neutrons and their development should be continued. Other sources of monochromatic neutrons, particularly of higher energy, should be built. The general problem of production of high energy particles is closely related both to the fundamental and to the programmatic research and should be encouraged.

B. Nuclear Physics Research Specifically Applicable to Atomic Bomb Problems.

1. Integral Investigations. The spacial and energy distributions of neutrons should be ascertained in the various models of the atomic bomb being pursued. Assemblies using inhibitors need study in detail. Measurements of the multiplication rate of neutrons, and its dependence on the degree of criticality should be made for all assemblies.

The possible use of instantaneously supercritical metal assemblies should be studied. A general investigation should be made of fast neutron reactors, particularly as possible sources of neutrons.

Composite assemblies should be investigated in some detail. The problem of nuclear predetonation needs study as well as methods for its reduction. There should be a special integral investigation of the properties of nuclear tampers or reflectors.

2. Initiators. It is particularly important to develop an initiator which acts at a time determined as optimum for the nuclear explosion. A lower background for the initiators is desirable. This may mean the use of less Po or other neutron producing material. In order, however, that this be done, a clearer understanding of the action of the initiator, and particularly of its efficiency, is needed.

Other methods of testing initiators should be investigated. The possible firing of atomic bombs for testing initiators, and particularly bombs containing a large amount of hydrogen, should be studied. Direct tests of initiators using very fast counters and large amounts of Po or other neutron producing material should be considered and possibly studied in some detail.

3. <u>Tests</u>. Any program for the development of atomic bombs must be accompanied by a testing program in which the bombs are actually fired. It will be essential for this testing program to have adequate nuclear observations on the course of the nuclear reaction. Efforts must be made, therefore, to develop further the methods of observation which have been started in the Trinity shot.

C. <u>Nuclear Physics Research Specifically Applicable to Controlled Critical Assemblies</u>.

1. <u>Piles (Slow Neutron Reactors)</u>. An investigation of the properties of pertinent materials which apply specifically to slow neutrons should be made. This should include crystal effects and a study of neutron resonances. The question of radiative absorption cross sections compared to fission as a function of energy of the incident neutron should be investigated for all active pile materials.

Artificial absorption introduced by pile operation particularly from fission products should be thoroughly investigated. A study should be made of the possible use of the burning out of impurities ordinarily encountered in pile materials.

2. <u>Fast Neutron Reactors</u>. The specific physics research problems here are similar to some of those described under B. There should, however, be a development of controlled fast neutron reactors, aimed at finding more about the nature of these reactors and of bombs, as well as to furnish copious sources of fast neutrons.

D. <u>Nuclear Physics Research Specifically Applicable to Problems of the Super</u>. The most important nuclear physics problems now needed for the study of the super are cross section investigations. Good measurements have already been made over rather limited energy regions. These should be duplicated and extended to all accessible energy ranges. The measurements should include the primary reactions which are encountered in the super as well as many secondary reactions. They should also include the possible investigation of new atomic processes or disintegrations which may occur at higher energies as yet not investigated, for example, fission or dissociation of light elements. The various cross sections which should be measured are listed below, and it is understood that these cross sections should include all scattering and disintegration processes.

D-D
D-T
T-T
H-T
H-D
n-D
He^3-D
He^3-T
He^3-He^3
n-T
He^4-D,
etc.

Measurements should be made of the number and energy of all resulting particles and γ rays, including directional effects.

The nuclear properties of possible wall materials when bombarded by the primary particles D and T will surely be needed.

The reaction with nitrogen by the above particles as well as N itself might conceivably lead to the detonation of the atmosphere. This possibility and the even more remote possibility of the detonation of the earth have been investigated by theory and are now considered impossible. However, these problems are so vital that they should be seriously reconsidered from time to time. Possible reactions should be measured so that the considerations can be made on a firm experimental basis.

E. Nuclear Research Specifically Applicable to Peace Time Developments.

1. It is quite desirable to ascertain the characteristics of the radiations generated by the various fission products and by other materials which have been produced by neutron radiation in piles. Detailed knowledge of the energy distribution of the emitted electrons and gamma rays should be obtained. Since these materials are practically limitless, first attention should be given to those isotopes which show greatest promise of use in chemical, biological, medical or industrial applications.

2. A search should be made for possible isotopes which are alpha active without strong accompanying gamma activity and which can be obtained in quantity for possible use as concentrated power sources.

3. The very remote possibility of a controlled thermonuclear reaction should be carefully studied. Such a reaction might use more abundant raw materials than the present sources of nuclear power. Since it is likely that the reaction would take place with higher energy neutrons, it might also lead to the production of new materials not obtained either from fast or slow neutron reactors. Such a thermonuclear reactor might also provide a source of tritium.

4. While many of the problems of power production do not fall in the scope of this summary, there should be investigation of the nuclear properties of the various elements which might possibly be used as moderators, levelers, reflectors, and coolants.

It is very difficult to make any valid estimate of the effort required to carry out the above program. Furthermore, it will depend on whether the programmatic work in particular is carried out in a single laboratory or in a large number of loosely connected institutions. For the programmatic work the former would probably be more efficient, but it is likely that the latter would be more productive for the fundamental work. In a single laboratory it is estimated that a staff of twenty-five Ph.D. physicists including five top men could probably in the space of five years make considerable headway on the programmatic research above. The total staff would of course need to be considerably larger and to include suitable numbers of junior scientists, technicians, and machinists.